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TO THE QUESTION OF IMPROVEMENT OF PROFILES OF RAILWAY WHEELS

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One of the burning questions of wagon and locomotive exploration on railways in the countries of the Central and Eastern Europe is the increased wear of a driving surface of the wheels. Especially it concerns their flange zone. The greater part of wheels gets in premature turning that results in significant idle times of a rolling stock, the charges connected directly with turning as well as with the replacement of wheel pairs for wagons or bandages for locomotives. It is obvious, that significant financial resources of railways are spent in this way.

It is necessary to note that the problem under consideration is an international one and, accordingly, scientists of the different countries are engaged in its solution with various efficiency. Various methods are offered for its solution , starting from simply rigid control over the maintenance of a running part of a rolling stock, to so exotic enough technical solutions, for example, applications of differential wheel pairs. Methods of increase of hardness of a superficial layer of wheels and rails should be attributed to most widely widespread technical solutions, for example, r f current or plasma hardening, and also lubrication of working surfaces of wheels and rails.

Improving the profiles of working surfaces of wheels and rails is one of possible variants of the specified problem solution. An attempt to consider contact interaction in a pair “wheel – rail” for various profiles of wheels and rails, including worn out has been done in action. In the latter case Talyrond traces of wheels and rails were sketched for a various degree of their wear. For example, on fig. 1 comparison of a new (a thin dashed line [1]) and a worn out (a continuous fat line) profiles of electric locomotive EU07 is used on the Polish railways is shown. Laser profilograph was used for drawing the worn out profile

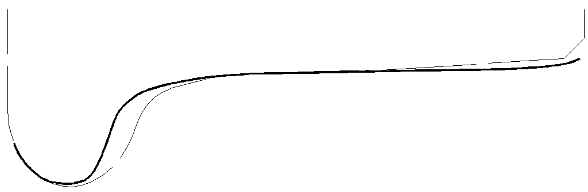

Fig. 1. Comparison of the new and worn out profiles for a wheel of electric locomotive EU07

The profile received as a result of scanning was interpolated with mathematical curve of high accuracy (polynoms of the third order or arches of circles). The similar approach was applied for contacting profiles of rails. I.e. it was possible to consider both new and the worn out profiles of rails. As a result, the technique allowed to define in each possible zone contact for initial points of profiles of a wheel and a rail local radiuses of curvature.

Quasi- Hertzian approach to the solution of contact problems of interaction of wheels and rails has been developed by the authors which allowed to investigate their interaction at presence of two-zoned ("two-point") contact [2, 3]. On its basis lies Hertz – Beliaev solution for each of contact zones of a wheel and a rail. The problem is considered in three-dimensional statement , relative positioning of surfaces, including interaction of wheels and rails are taken into account at nonzero corners of attack. From finding points of possible contact the minimal distances between cooperating surfaces are determined for which local radii of curvature are calculated. Defining of stresses in case of one-zoned contact does not cause difficulties, but in a case of two-zoned contact it is necessary to define, how contact efforts are distributed between zones of contact. The iterative algorithm in which basis definition of rapprochements of cooperating surfaces under action of the set contact efforts is necessary has been worked out for their finding. The last are corrected from a compatibility condition of deformations.

It is obvious, that such approach assumes to use of all assumptions of Hertz theory, that certainly brings a significant error in the receive solutions. Nevertheless this approach is considered as having a certain closeness. It allows to model possible arrangement of contact zones for various cooperating profiles of wheels and rails, including those being developed. After carrying out of primary researches with use of the developed algorithm and the computing program researches specified to strength of the calculation, for example, with the use of FEM, and also the analysis of stability of movement of a rolling stock with new profiles by means of any of programs of solid-state modeling, for example, ADAMS/RAIL or MEDYNA should be added.

On fig. 2 results of modeling of cross-section displacement of a wheel with a profile 28 UIC-140 concerning rail UIC 60 starting from the central position of wheel pair till the moment of contact in flange area are shown.

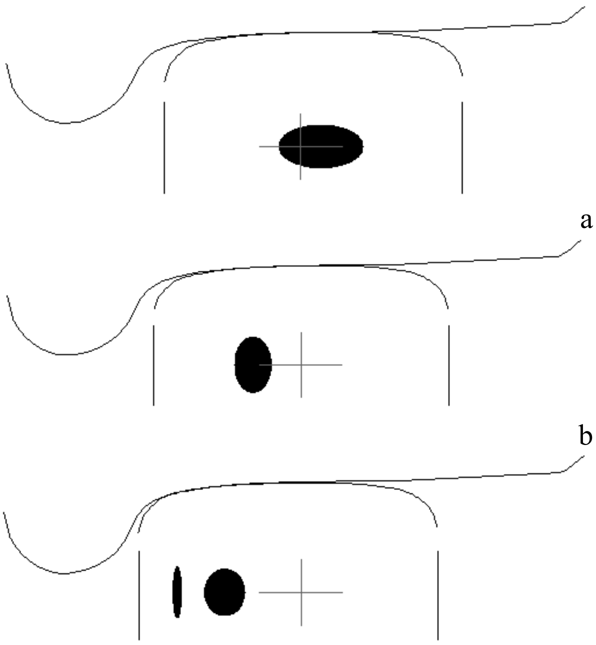

Fig. 2. Distributions of contact zones at cross-section moving a wheel 28 UIC-140 concerning rail UIC 60 for various positions of a wheel

As it is apparent from the given figures, profiles of wheels and the rails, employed on the European railways are those, that the arrangement of contact zones constantly changes. Here at calculations it was accepted, that on a wheel pair axial loading equal 250 kN operates. The rail is established with canting 1:40. For the central arrangement of a wheel pair in a track (fig. 2a) exists one large enough central zone of contact with rather low level of contact stress (881 MPa). At the displacement of a wheel pair (on fig. 2b) to the right, the zone of contact moves closer to a flange. Its form changes, as the size of the half-axle of a contact ellipse changes and the level of stress grows up to 1545 MPa. Then formation of two-zoned contact (fig. 2c) follows, and the level of contact stress in a flange zone reaches 2618 MPa. As the problem is considered in elastic statement such stresses do not correspond to the validity any more. In a flange zone plastic deformations should appear, and a level of stress even should be higher. However, the carried out calculation can signal that at interaction of a wheel and a rail in a flange zone there can be plastic deformations even at action of axial loadings not exceeding static.

Similar calculations have been carried out for wheels and the rails employed on railways of the countries of the former USSR. In particular, on fig. 3 results of modeling of cross-section moving of a wheel with a profile in accordance with GOST 9036-88 concerning rail R65 are shown.

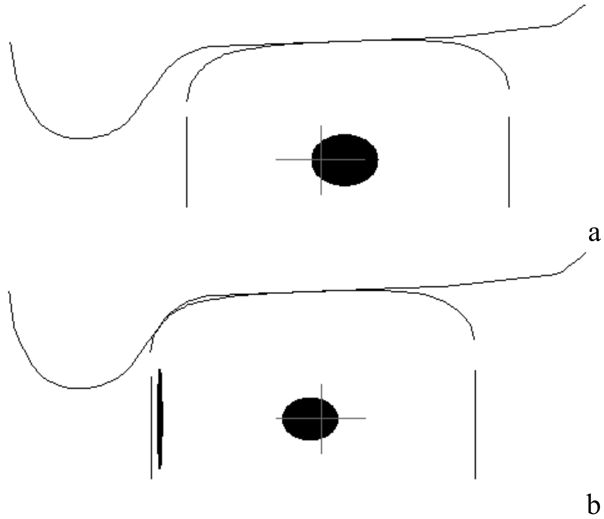

Fig. 3. Distributions of contact zones at cross-section moving a wheel of GOST 9036-88 concerning rail R65 for various positions of a wheel

It is necessary to note that the process of interaction of a wheel and a rail in this case occurs in a completely different way. Axial force accepted is same as in the previous case, canting 1:20. For the central arrangement of wheel pair (fig. 3a) exists one contact central zone, the level of stress in which is a little bit higher, than in the previous variant 1071 MPa. Because the wheel on the central site has a constant obliquity, at displacement of a wheel both to the right, and to the left, the contact zone does not change neither in size, nor in level of an intense condition, or in arrangement. It is going on till the moment of contact of a flange with a lateral surface of the head of a rail (fig. 3b). At this moment an additional a flange zone of contact with a very high level of stress (in elastic statement up to 3609 MPa) appears. It is quite obvious, that here occurs intensive plastic forming of a wheel surface.

There is one more important fact influencing the wearing of a wheel surface in a flange zone. As it is apparent from the comparison of figures 2c and 3b, two-zoned contact is taking place in them. However, there are crucial distinctions between figures. In the first case an arrangement of contact zones in relation to one another is close enough and distinction of local radiuses of a surface of a wheel is insignificant. In the second case, the zones located in relation to one another far enough have considerably distinguished local radiuses. It promotes the occurring of a slip in a flange zone.

The specified factors appreciably influence occurrence of intensive wear of wheels in a flange zone, that finally results in their undercut. Even in the greater degree the specified factors influence the undercut of a flange at nonzero corners of attack of the wheels. In this case the flange zone of contact is as though put forward for the distance called lozenging. Thus, the level of plastic deformations in it is even higher.

For specification of the problem solution the finite element method was used. In particular, deformation of wheels and rails under the action of set of the loadings working on them while in service was considered separately. For example, the thermal deformations of wheels caused by block braking of various intensity were taken into account as well as contact loadings in various zones. For example, on fig. 4 distribution of temperatures in the carload wheel used on the Polish railways [4] is shown.

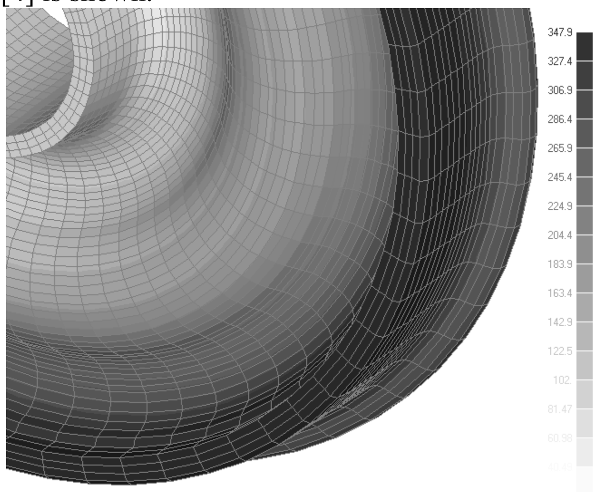

Fig. 4. Distribution of temperatures for carload wheels at block braking

Deformation of wheels and rails on the whole influences the change of a relative arrangement of their working surfaces. The received fields of displacements of wheels and rails were used further for specification of mutual position of working surfaces of cooperating wheels and rails. For example, on fig. 5 distribution of stress in section of a wheel of GOST 9036-88 under action of the thermal loadings caused by block braking is shown. Deformation of section is shown also.

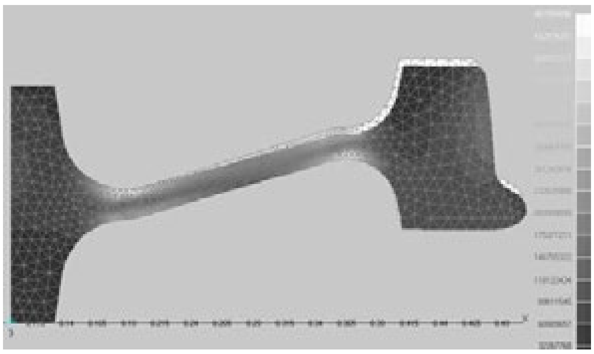

Fig. 5. Distribution of radial stress in section of a wheel of GOST 9036-88 under action of thermal loadings

For the solution of the specified problems geometrical modeling of the objects under consideration in any of CAD-programs has been carried out. Their geometrical image further was imported to the finite - element program. Discretion of the considered objects was carried out in a half-analytical mode. On fig. 6 finite - element discretion of the considered near contact areas is shown. In particular, the new wheel with a surface profile in accordance with GOST 9036-88 is considered at its interaction with new rail R65.

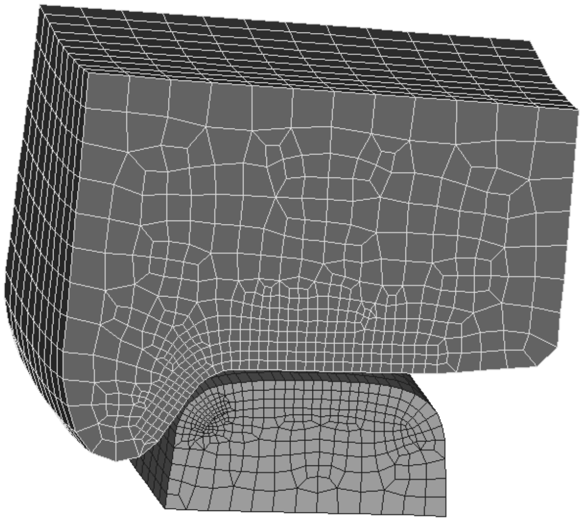

Fig. 6. Finite - element discretion of the considered near contact areas

For FE calculations the software of MSC.Software NASTRAN and MARC companies was used. In comparison with calculation with the use of quasi- Hertzian approach, it was possible to take into account friction between interacting surfaces. However, owing to the complexity of the contact problems solution in finite - element statement, long time spent on one calculation, such calculations were carried out only for the chosen relative positions of a wheel and a rail. The problem was considered only for near contact zones of a wheel and a rail, and at the task of displacements on its borders the solution carried out preliminary for wheels and rails separately was used. This solution already took into account relative skews of interacting surfaces.

As a result of the carried out researches distributions of contact zones, stresses in them for various profiles of working surfaces of wheels and rails have been determined. For example, on fig. 7 distribution of contact nodal forces (analogue of contact stresses) for a new wheel with a profile of GOST 9036-88 is shown, at its interaction with rail R65. This figure shows good conformity with results of calculation according to the technique described above (see for example, fig. 3b).

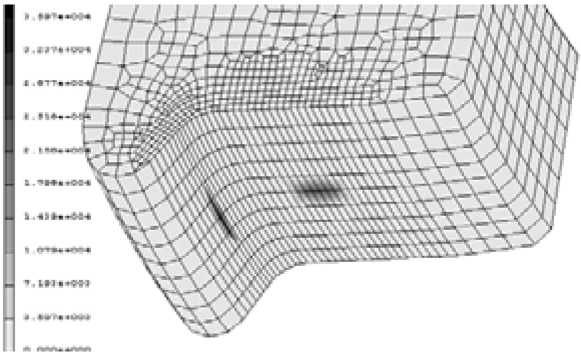

Fig. 7. Distribution of contact nodal forces for two-zoned contact between a wheel of GOST 9036-88 and rail R65

The considered technique finite - element calculation took into account friction between surfaces, and also plastic deformation of interacting bodies. The case of a wheel and a rail interaction corresponds to loading of a wheel vertical force 12,5 kN and lateral 10 kN is shown on fig. 7. The maximal contact stresses in a flange zone reach 4520 MPa. It is quite obvious, that such a high level of stress is the reason for occurrence of plastic deformations. On fig. 8 distribution of such equivalent plastic deformations for the mentioned above case of contact is shown.

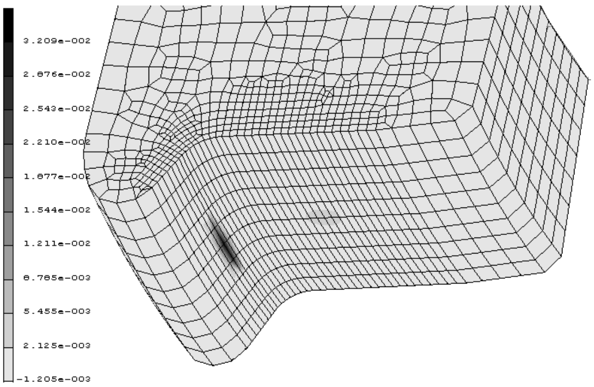

Fig. 8. Distribution of equivalent plastic deformations for two-zoned contact between a wheel of GOST 9036-88 and rail R65

As it apparent from the resulted figure, plastic deformation in the central contact zone is insignificant. Thus, in a flange zone of contact equivalent plastic deformations reach the amount of 3,2 % that results in cutting a flange.

In connection with the mentioned problems the researches of contact interaction and wear of wheels and rails of various designs were carried out by the authors. There are some works concerning the design of rails. However, peak efficiency has been achieved at the development of new designs of profiles of wheels of wagons and locomotives. For them intensity of wear of working surfaces in a flange zone first of all has decreased.

In particular, profiles DMetI with indexes VB and VR for wagons, and also LB and LR for locomotives have been developed. All the defined profiles are based on use of a variable conicity of generatrix at their construction. Using of biases 1:20 and 1:7 for standard profiles on a working surface is a tribute to out-of-date technologies when for turning machine tools A41 were used. At present there is no need to use such profiles.

Profiles DMetI VB and LB (base) have thickness of a flange of 33 mm, VR and LR thickness of a flange of 30 mm (repair). The first as well as the second in particular allow to save essentially the resource of wheels and bandages at their turning. They allow to lower greatly the level of contact stress due to redistribution of contact zones. Especially, at the influence of lateral force and realization of flange contact the case of one-zoned contact that is shown on fig. 9 is observed. All parameters of a problem are taken same as in the previous case.

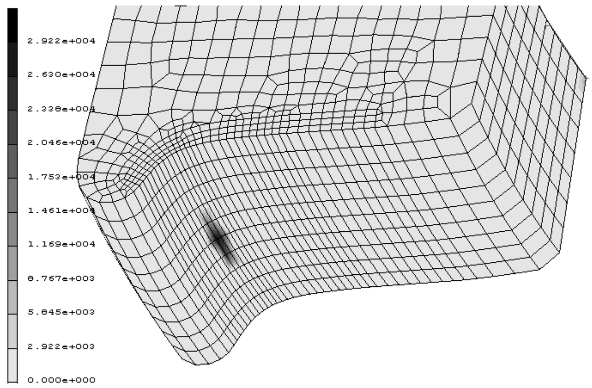

Fig. 9. Distribution of contact nodal forces for two-zoned contact between a wheel with profile DMetI VR and rail R65

The analysis of contact stresses in a flange contact zone shows that their level makes 3118 МПа, i.e. 1,45 times are less, than in a case of contact of a wheel with a standard profile.

Decrease of contact stress also allows to reduce the level of plastic deformations. Figure for the designed field of plastic deformations is not resulted, as externally it practically coincides with fig. 9. Thus the maximal equivalent plastic deformations are equal 1,28 %, i.e. in comparison with a standard wheel their level is reduced in 2,5 times.

Profiles DMetI have passed test for wheels of carriages and have shown high efficiency. Such profiles now are effectively used for turning wheels of locomotives in Ukraine, Russia and other countries. According to various depots intensity of wear of wheels has decreased in 20 up to 50 %. Thus, more than double economy of the resource of bandages is reached. Let's note also, that consummation of new profiles in a locomotive facilities became possible due to the development of the new tools for turning wheels among which the most difficult tools are shaped mills which are submitted on fig. 10.

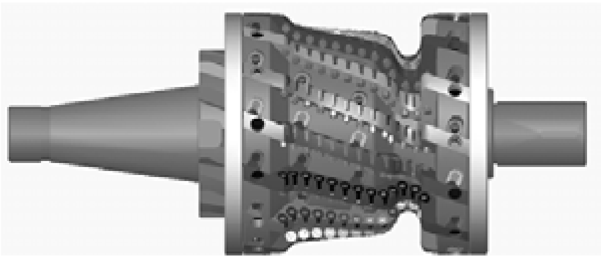

Fig. 10. Shaped mills for turning bandages of locomotives on profiles DMetI

Similar results have been received at the use of new profiles for railway tanks. But the greatest efficiency is received at the use of new profiles on an industrial railway transportation. It is caused by the fact that in conditions of ore dressing combines wear has essentially abrasive character. Reduction of slip in a flange zone reduces intensity of such wear. As a result, with the use of the described development it was possible to lower essentially intensity of wheels wear of wagons and locomotives on a number of the largest ore dressing combines, among which Mikhajlovski, Kachkanarski, Poltavski, etc.

Consequently, the effective solution of the problem of wear of wheels of wagons and locomotives is found. The defined solution can be used for designing profiles of wheels and bandages for various conditions of exploration, and also can and profiles rail heads should be changed. It is necessary to note only, that such changes should be carried out together with the change of profiles of wheels. Practicing until recently in railways of the countries of the former USSR inconsistency in actions of the departments responsible for a rail facilities and a rolling stock, did not promote the solution of a considered burning problem. Let us also mention, that the specified changes of profiles of working surfaces of wheels do not contradict, but only promote carrying out of other actions directed on decrease of intensity of wear of wheels and rails.

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SUMMARY

The article under consideration is devoted to the decision of reduction in intensity of wear of wheels and rails issue. As the solution it is offered to use new profiles of wheels which have the lowered level of contact stresses, in particular at the interaction with rails in a flange zone. At such interaction the level of plastic deformations in the specified zone is also reduced. Modeling contact interaction of wheels and rails is carried out by means of two techniques, one of which is based on application of quasi - Hertzian approach, and the second one employs a finite element method.